Unwritten potential: Changing the Face of Solar Energy with Carbon Nanotubes

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What Are Carbon Nanotubes?

Single-walled carbon nanotubes (SWCNTs) are cylindrical structures with a hexagonal shaped pattern. Despite being a relatively new discovery, they already have practical applications, mainly as a strengthening agent in sports equipment such as tennis rackets and bicycles. The size of any given carbon nanotube depends on the method in which it is produced, but it general has a diameter of roughly 1 nm (10^{-9} m). Despite their small diameter, they can have lengths on the order of millions of times their diameter.

Developmental Diversity

The trouble with the synthesis of the carbon nanotubes is that they range greatly in their physical and chemical properties. As well, although the raw materials are relatively inexpensive, the production methods are not always so. Each method of production results in vastly different conformations of nanotubes, as shown in figure 1, with the possibility of multiple types forming. As a result, significant research has been conducted to find methods that produce only particular configurations of nanotubes while being economically viable.

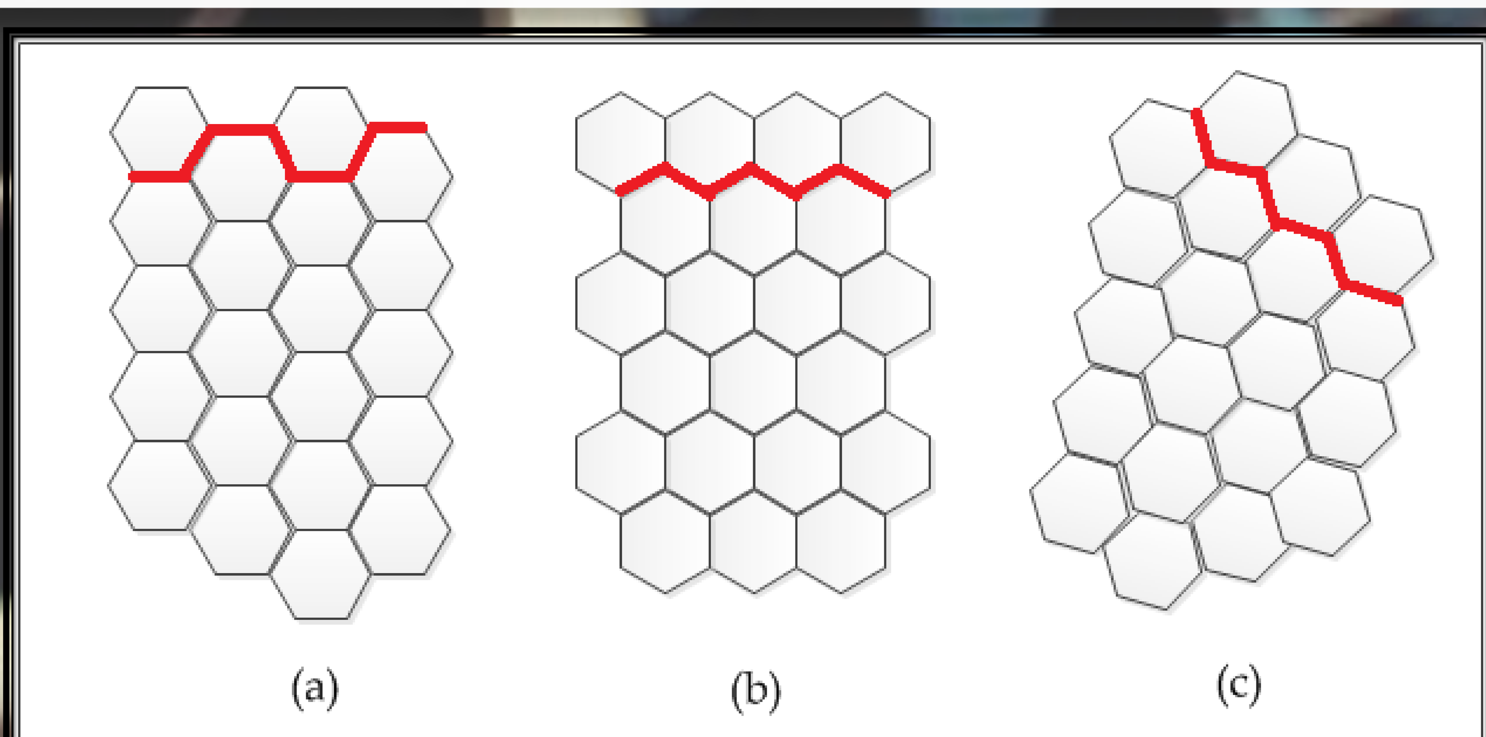

Figure 1) The different structural conformations of single-walled carbon nanotubes walls. The three structures are armchair (a), zigzag (b), and chiral (c). The red lines show the different orientates of the carbon bonds.
Modified from: http://www.intechopen.com/source/html/16801/media/image2.png

Unique Properties

This specific structure of carbon has a variety of unique properties that make them of interest for usage in solar cells.

- Carbon nanotubes can be designed to absorb visible light, as well as infrared and ultraviolet.
- Specific configurations of the SWCNTs can be roughly 1000 times more conductive than copper.
- Carbon nanotubes are 5 times stronger than steel, while remaining flexible.

Production methods

There are three main methods of production of SWCNTs: arc discharge, laser vaporization, and plasma spraying. Each of these methods have their own individual advantages and disadvantages associated with them. Table 1 highlights these different production methods and how they differ.

Arc Discharge

In the method of arc discharge, two graphite rods are separated by a few millimeters and an electrical current is run between the rods. Graphite powder mixed with metals such as nickel or iron can be used to increase the rate of carbon nanotube deposition. A black layer of soot is produced which contains the nanotubes.[2]

Method	Advantages	Disadvantages	Yield
Arc Discharge	• High Quality • Relatively Inexpensive	• Short length • Random sizes produced	30-90% of starting material
Laser Vaporization	• Diameter range can be controlled. • Mainly SWCNT produced.	• Unwanted forms produced • Equipment is expensive.	~70% of starting material
Plasma Torch	• Continuous Process • Multiple SWCNTs can be produced.	• Minor defects in the SWCNTs	1.5-2.0 g/min

Table 1) The main production methods for SWCNTs and the advantages and disadvantages of each.

Laser Vaporization

A slightly different starting material is used in this method. Instead of using a pure graphite rod, small amounts of nickel, cobalt, and iron are infused into the rod. This rod is placed in a high temperature chamber that is filled with an inert gas such as hydrogen or argon. By using a laser, the material in the rod is vaporized and the resulting gas condenses on the surface of the chamber forming the nanotubes.[3]

Plasma Torch

For the plasma spraying method, a gas mixture of hydrogen and argon is superheated until the molecules ionize, and a plasma is created. By spraying a liquid composed of hydrocarbons through this plasma, the carbon particles are heated to a point where they come together to form the carbon nanotubes. This method can be run continuously and has the potential to produce large amounts of SWCNTs.[4]

Usage in photovoltaics

Until recently, the usage of SWCNTs in photovoltaic cells has mostly been ignored in favor of more cost-effective silicon based cells. However, advancements in the synthesis of the carbon nanotubes have opened the possibility for further development. This is due to SWCNTs being able to effectively transport excited electrons to generate voltage. Solar cells operate on the basis of excitons that are created from incoming electromagnetic radiation. As the energy strikes the photovoltaic cell in the form of a photon, the energy is transferred to an electron that is excited out of its normal orbit. This results in a positive area that the electron orbits. To harness this newly captured energy, the electron must return to its original orientation, resulting in energy which excites the next electron and so on.

One of the greatest advancements in the development of successful carbon nanotube solar cells was by Gong and others (2014). They managed to use a variety of different configurations of SWCNTs in conjunction with other materials to nearly double the power output of similar cells. This was accomplished through the usage of different carbon nanotubes that were able to absorb a wider range of incoming electromagnetic radiation. Figure 2 shows the different layers used to fabricate the solar cell.

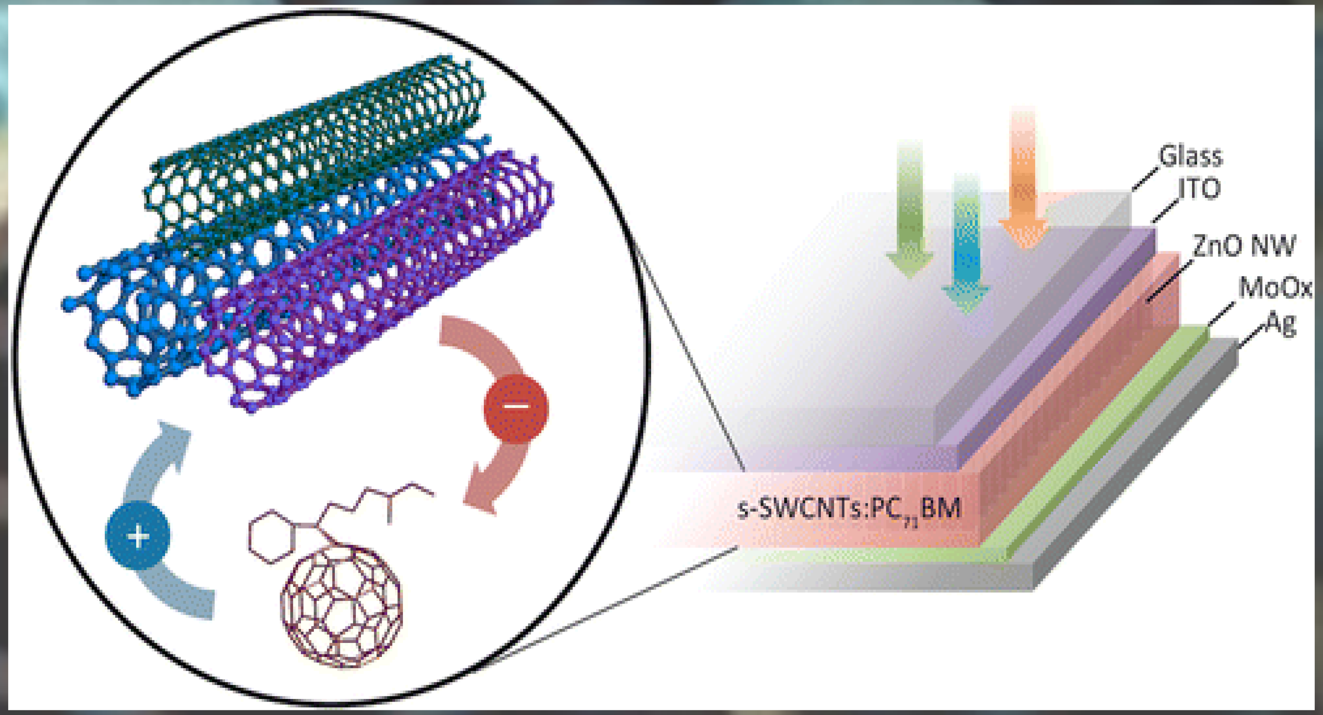

Figure 2) The composition of a photovoltaic cell using multiple forms of carbon nanotubes. The usage of multiple layers allows for greater absorption of energy.
Modified from: Gong et al. (2014)

Conclusion

While there are currently issues with the usage of SWCNTs in photovoltaic cells, there is the potential for further improvements to be made. Already, methods have been created that have the potential to be used for industrial-level production of carbon nanotubes. This would help alleviate the economic hurdle that carbon nanotube must overcome to compete in the solar cell market. While the field of carbon nanotubes has not produced any marketable solar cells, the potential is present for efficient solar cells that could one day eclipse the competition.

Literature Cited

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